Thermal hydrolysis of secondary sewage sludge and viscosity decrease

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Abstract
Wastewater sludge treatment via anaerobic digestion commonly involves thermal hydrolysis processing as a pre-treatment step. Using high temperature, thermal hydrolysis is able to condition the sludge such that the performance of the subsequent anaerobic digestion is greatly improved. It has also been established that thermal hydrolysis processes results in significantly reduced sludge viscosity. However, the evolution of the sludge viscosity over the thermal hydrolysis treatment period has not been fully examined. A better understanding of the rheological behaviour of sludge during thermal treatment is valuable in process and equipment optimization and design. This work examines the viscosity drop of thickened waste activated sludge (10 wt% solids) over time, under high temperature conditions. It was found that the sludge viscosity decreases gradually over the treatment period and the final viscosity is decreased irreversibly as a result of increasing treatment temperature.

Keywords
Thermal hydrolysis; sludge viscosity; waste activated sludge.

Introduction

Thermal hydrolysis is a pre-treatment process which uses high temperatures to condition the excess sludge produced in wastewater treatment plants before it is fed into an anaerobic digester. As a result of pre-treatment the digestibility of sludge is improved, which results in increased methane production during anaerobic digestion (Neyens and Baeyens, 2003). Simultaneously, the sludge viscosity is also substantially reduced, which allows the increase in loading rate of sludge solids fed into the digester (Perez-Elvira et al., 2010). Thermal hydrolysis treatment temperatures range between 100 – 180 °C whereas treatment times are between 30 to 60 minutes (Hii et al., 2014). Thermal hydrolysis also typically occurs at elevated pressure conditions, such that the sludge remains in the liquid phase during treatment. Although the rheological behaviour of thermally treated sludge has been investigated (Feng et al. 2014), there has been limited studies on sludge rheology during thermal hydrolysis processes. The current work examines the evolution of the apparent viscosity of a thickened waste activated sludge (WAS) at a constant shear rate during thermal hydrolysis treatment at various treatment temperatures.

Materials and methods

Waste activated sludge was thickened to 10% solids concentration by centrifugation. Using a rheometer (TA instruments) equipped with a pressure cell, the viscosity of sludge samples were measured in-situ over time. Sludge samples were introduced into the rheometer pressure cell at 25 °C and then pressurized to 5 bar using nitrogen gas. It is then heated to the desired treatment temperature. Once reached, the temperature was held constant for 1 hour. Over the 1 hour period, the apparent viscosity was measured at a constant shear rate of 100 s^{-1}.

Results and discussion

Figure 1 shows the viscosity change of 10 wt% WAS over 1 hour at various treatment temperatures measured at a constant shear rate of 100 s^{-1}. It can be seen that the apparent viscosity decreases as the treatment progresses over 1 hour. At each treatment temperature, the decrease in apparent

viscosity is rapid during the initial 15 minutes, after which it decreases gradually, although this becomes less pronounced with increasing temperature. The apparent viscosity change is most likely a result of the solubilisation of the sludge particulates as well as the hydrolysis of macromolecules in the sludge, which is suspected to occur during sludge thermal hydrolysis (Neyens & Baeyens, 2003). Figure 2 shows the average apparent viscosity of the sludge after treatment at various temperatures measured at 100 s^{-1} shear rate over 5 minutes. The measurements were taken at 25 °C once the samples have cooled down after being measured at various treatment temperatures. Untreated sludge sample was also measured for comparison (represented in Figure 2 at 25 °C). It can be seen that the apparent viscosity after being exposed to the treatment conditions is reduced irreversibly. The apparent viscosity also decreases with increasing treatment temperature in a linear fashion and may be an indication of the degree of solubilisation or hydrolysis during treatment.

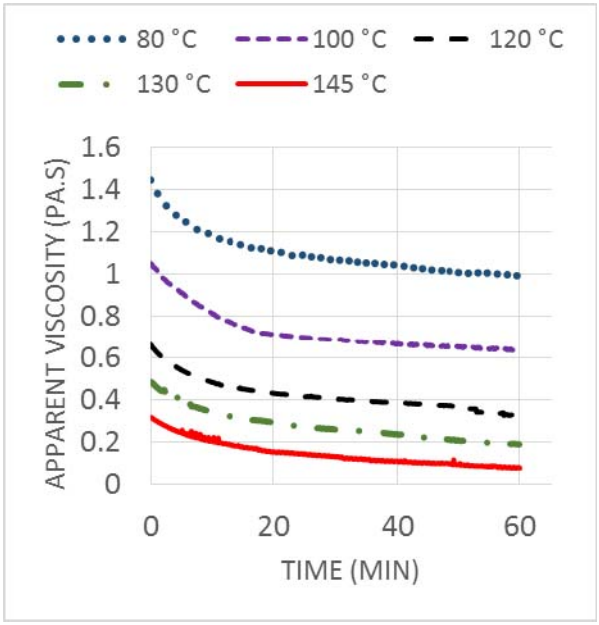

Figure 1. Apparent viscosity change of waste activated sludge (10 wt%) under constant temperature and 5 bar pressure over 1 hour. Viscosity measured at 100 s^{-1} shear rate.

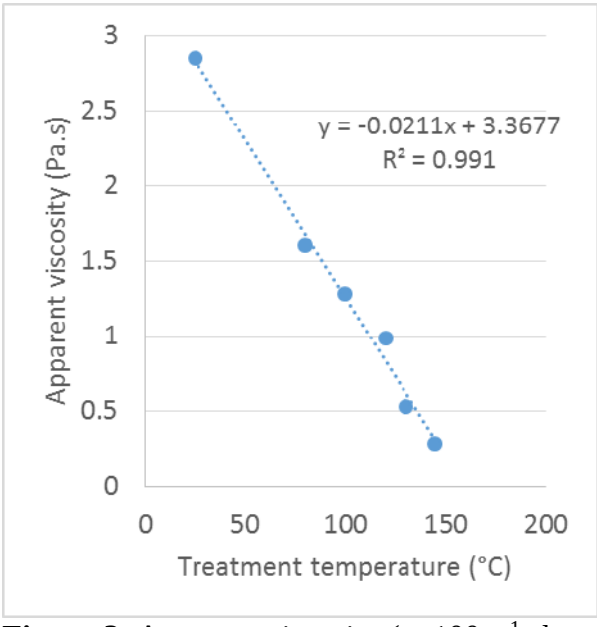

Figure 2. Apparent viscosity (at 100 s^{-1} shear rate) of waste activated sludge (10 wt%) after 1 hour treatment at various temperatures. The point at 25 °C represents an untreated sludge.

Conclusion

The apparent viscosity of thickened waste activated sludge decreases irreversibly as a result of increasing thermal hydrolysis temperature.

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